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SCIENCE AND TECHNOLOGY

ITALY: INDUSTRIAL ROBOTICS AND OUTLOOK FOR THE SECTOR

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EUROPE/LATIN AMERICA REPORT

SCIENCE AND TECHNOLOGY

ITALY: INDUSTRIAL ROBOTICS AND OUTLOOK FOR THE SECTOR

Turin MEDIA DUEMILA in Italian No 11, Dec 86 pp 113-134

[Excerpts of "Part Two" of the report of the Committee of the Prime Minister for Science and Technology written by Bruno Lamborghini and Carlo Eugenio Rossi; Part Two prepared in June 1985]

Contents

Introduction

Industrial robotics is one of the leading areas of the complex, wide-ranging sector of industrial automation.

Originally, the robot was the product of the integration of a mechanical technology with an electronic technology. Development of the robot has concentrated on three main areas, mechanical capabilities, sensory capabilities and control systems and, last, artificial intelligence.

The objective of this study is to analyze the manufacturing and market structures for industrial robotics, providing the material needed for an evaluation of the factors affecting the development and spread of industrial robotics within Italian industry.

We will also compare the situation in Italy with the experience acquired by other countries since this will allow us to trace possible areas of development for this sector as well as the impact--both direct and indirect--which government has on this sector as a result of industrial policy.

The term "robot," which is often used in a broad sense to indicate the entire process of factory automation, should in fact be used solely with reference to machines used for handling, processing, and assembly operations.

Here again the meaning given to the term "robot" varies from one country to another and from one user to another. Because of this, we need an introduction which provides an exact definition of the scope of this study.

According to the broadest definition of this term, which has been adopted by the Japanese and by the East European countries, the robots available today on the market can be classified on the basis of the type of input and the method of "learning" (the ability of the robot to interact with the surrounding environment). The following categories are used:

--Robots for manual handling, directly controlled by human beings, with simple functions involving the loading, unloading and positioning of parts;

--Pick-and-place robots for handling operations, carrying out loading and unloading of process machines;

--Playback robots, capable of repeating a programmable operating

sequence on a continuous basis;

--Robots with numerical controls, capable of performing the operations requested by following memorized numerical information concerning positions, operating sequences, and operating conditions;

--Intelligent robots, with sensory and processing capabilities which enable them to determine their own behavior.

In the West, on the other hand, the first two definitions given above are not generally used. Some users prefer an even more restrictive definition which excludes playback robots, thus restricting the sector to the last two categories only, that is, servo-robots.

The fields of application of these robots depend on the complexity of the technologies used, particularly the incorporated software, and range from operations involving movement only to operations involving different manufacturing processes (e.g. welding, painting, cutting, assembly) and inspection of the finished part.

Robots are the merging point of a vast and complex set of mechanical and electronic technologies which tend to take the form of integrated automation systems, systems which are moving toward the "automated factory" of the future.

Factory automation systems cover the following four main categories:

--Design support systems;

--Production programming and control support systems;

--Automation systems for storage and movement;

--Automation systems for the manufacturing and assembly processes which, in turn, are classified as nonflexible or special automation systems and flexible automation systems.

The last category, which today represents the most advanced stage toward the "automated factory" is also considered in this study, since robots represent the main functional component of these new assembly systems.

Part One

The International Context

1.1 The Technological Evolution

Industrial automation, in the sense of the automatic execution of sequences of operations specified by a preset or predefined program and without human intervention during the process, has evolved from the original concept of single machines to the broader concept of the processing system, and has now reached the even more general level of the manufacturing system (that is, design, processing, assembly, storage, testing and shipping of the products).

Moreover, with the utilization of increasingly flexible systems, nonflexible automation has now evolved into multipurpose automation, making it possible to use the same equipment at different times and in different places for a variety of manufacturing processes, since the manufacturing program can now be modified without difficulty.

Rather than simply giving a description of the technological evolution of industrial automation--starting from the introduction of numerically-controlled machines and going on to the creation of "processing centers" in the second half of the 1960s, to finish with the "processing cells" of the second half of the 1970s and subsequent developments involving the integration of different "cells" to form computer-controlled systems (Flexible Manufacturing Systems)--we feel that it will be helpful to outline the economic implications of this evolution.

A. The automation of manufacturing processes has led to substantial changes in company logistics and organizational structures. These changes range from the simple reorganization of the layout of departments to changes in the production method employed and the actual organization of the work to be done, redefining the number of employees assigned to different areas and the qualifications required of these employees.

In particular, the use of robots entails extensive modification of the information and communications system, as greater interaction is needed between the machine and its environment, thus increasing the part played by coordination and data exchange processes in the optimization of the system.

B. The decision to adopt automated manufacturing systems implies a shift away from a "technical" evaluation of the cost-benefit ratio (that is, increased productivity and a reduction in the unit labor cost

weighed against the high capital investment initially required), and a move toward a general evaluation of, on the one hand, the real increase in the flexibility of the manufacturing systems and, on the other hand, the impact on industrial relations.

C. Electronic components and the development of software programs for machine control and coordination are playing an increasingly important role in industrial robotics. This has led to a merging of technological areas which were once clearly defined and to a situation in which software is becoming more important than hardware.

Continuous developments in technology mean that, to an ever greater extent, electronic automation will be able to provide flexible, "intelligent" capabilities, with a cost-capability ratio that will be increasingly attractive and with far greater levels of reliability and productivity than those which are possible using human resources.

There can be no doubt that the manufacturing sector will undergo a complete transformation as a result of the introduction of these technological process innovations, and this will have direct effects on the whole economy.

It is possible that the substantial increase in productivity and the massive reduction in the unit production cost which the use of robots in the manufacturing process will make possible will produce a situation in the manufacturing sector similar to the situation we have already witnessed in the agricultural sector, that is, a substantial reduction in the labor force and in the role played by the sector in the economy as a whole, at least in the stages which are concerned specifically with the manufacturing process.

However, the evolution of this process of innovation (a continuous and far-reaching process) will be accompanied by the development of new services for industry, as well as the development of new professional roles and responsibilities and the creation of new business opportunities.

Finally, government will play a decisive role within this framework, particularly with regard to the development and encouragement of research and development activity.

1.2 World Supply

The general characteristics of the technological development of industrial robotics discussed above provide us with the necessary premises for a more in-depth analysis of the way in which supply and demand in this sector are structured in the three main areas of the

world involved in this technology, that is, Japan, the United State, and Europe.

Japan

The main development factors which enable Japan to maintain its position as world leader in both the manufacturing and utilization of robots are the following:

--The high degree of integration between the industry and the financial sector;

The ready availability of medium and long term credit, combined with a low level of indebtedness due to the fact that banks and insurance companies are directly involved in the capital formation of companies, has provided the necessary financial support for the growth of innovative industrial companies such as robot manufacturers;

--The interaction between MITI (Ministry of International Trade and Industry), universities, and industry in defining the basic strategic objectives and the frame of reference.

Direct financing of pure and applied research, tax relief (Mechatronics Investment Promotion, Tax System Small Business), soft loans (Small Business Finance Corporation, People's Finance Corporation, and Japanese Development Bank loans) and leasing operations (Japan Robot Leasing Company) constitute the main operating instruments adopted by MITI for the development of technology and the use of robots and flexible systems of industrial automation.

--The fact that the Japanese school and university structure is dynamic and well integrated with the industrial sector, and is capable of producing specialists and researchers who can be inserted into the manufacturing system without delay.

This does not mean, however, that there are no weaknesses. The main weaknesses are a limited domestic market and the fact that the country's export markets are extremely distant. Japanese companies get around these obstacles by locating manufacturing activity abroad and by increasing the number of international agreements made. The majority of these agreements concern the granting of manufacturing and sales licenses and/or joint manufacturing initiatives.

The Japanese supply structure consists of about 80 companies. Supply, which is oriented toward the mass production of standard machines has, until today, been destined mainly for the domestic market (75 percent of production)..

Manufacturing is not highly concentrated. It is frequently an activity of secondary importance, accounting for about 2 to 3 percent of sales and carried out by large, highly diversified electronics groups as well as by users of robots who have acquired experience in applications and supply capabilities and, finally, by a few specialized manufacturers. According to JRA (Japanese Industrial Robot Association), only 33 percent of manufacturers are large companies, while 40 percent of companies have a payroll of fewer than 500 people.

Recent developments in this sector testify to a fairly radical revision of the manufacturing strategy adopted by Japanese companies.

What is happening is that, rather than supplying single robots, companies are now supplying flexible manufacturing systems (FMS), consisting of islands of automation managed by computer hierarchies and grouping together several numerically controlled work centers.

In this way, the growing number of agreements for commercial and technological collaboration with domestic and overseas partners are being accompanied by changes in the product.

Europe

The areas of strength in the sector of industrial robotics in Europe are the following:

--The high technological level of the robots, based mainly on a considerable degree of electromechanical know-how combined with electronic expertise and innovation;

--The approach to production, which is similar to the American approach, that is, supplying complete automation systems designed to meet different user requirements.

The weaknesses in the supply system in Europe, on the other hand, are the following:

--The highly fragmented nature of the markets and their limited size;

--Great differences in the respective technological levels of users;

--The lack of an EEC industrial policy which would merge and direct not only the R&D activity but also the commercial and manufacturing activities of companies, thereby avoiding duplication and waste of the allocations made by individual countries.

Only in recent years have some steps been taken in this direction.

The EEC Esprit program provides financing for a number of projects as part of the five specific projects whose objective is to support precompetitive research. These projects are concerned with computer-aided manufacturing systems (CAM), particularly system architectures, CAD-CAE (Computer-Aided Design Engineering), CAD-CAM (Computer-Aided Manufacturing), sub-systems and robotics components (including sensors). The OSA program (Open System Architecture), which already has been approved by all the leading European operators, is now (June 1985) waiting for formal authorization from the EEC for the development phase to be started.

The objective of the OSA program is to make the robots used in "manufacturing islands" compatible with each other. The first phase of implementation of this initiative will require approximately 200 man-years, with a financial outlay that is estimated at several tens of billions of lire and involving 17 companies in 6 different countries.

The OSA precompetitive project, which will produce a laboratory prototype to be subsequently developed from an engineering point of view, will thus lay the foundations for a transition from single "islands" to full integration of the various phases of manufacturing using robots (automated manufacturing).

A program which is being developed in parallel to the OSA program is the Brite program, which aims to strengthen collaboration between industry and the research sector regarding the application of industrial robots, achieving this by means of pilot projects and demonstrations in the field of flexible automation, robot control systems and new methods of testing (including computer-aided testing).

This will be a 4-year program. Of the total allocation of 125 million ECUs (approximately 175 billion lire), 65 million ECUs are for 1985-86. The EEC will finance 50 percent of the cost of each project.

At a national level, there are a number of programs which concern the sector of industrial automation either directly or indirectly. These include:

--In France, in addition to a series of government agencies and specific programs for the development of innovation and investments in the sector of factory automation (Robotics billion, Meca procedure, Developpement de l'automation de la production [Development of Manufacturing Automation]), specific interventions are also planned for the restructuring of the machine tool sector (Plan machines outils [Plan for Machine Tools]) and for the support

of R&D activity (Automatisation robotique avancee [Advanced Robot Automation]) and allocations by ANVAR [National Agency for the Implementation of Research].

--In Germany, the "fertigungstechnik" [manufacturing technology] program, approved in 1984, is intended to provide support for the development and diffusion of design support systems, flexible automation, and industrial robotics by subsidizing 40 percent of the cost of the project.

There are also research structures that are concerned specifically with R&D, particularly for purposes of application, as well as with subsidy programs for small and medium-sized companies which are automating their manufacturing processes;

--In Great Britain, the general support measures for process automation (Support for Innovation funds) are accompanied by specific programs (the Robot Support Program, the Flexible Manufacturing Systems Scheme and the Avanced Manufacturing Technology Scheme) and by government bodies set up not only for research and development but also for the application of robot technologies and industrial automation.

The European robotics sector consists of about 50 major companies, the majority of which are located in West Germany and Italy.

Manufacturing of robots in Europe is characterized by the fact that production is concentrated in small and medium-sized companies, operating in both the electronics sector and the machine tools sector, and with an average payroll of 25 to 30 people. For these companies, industrial robotics respresents only a part of their sales.

In Europe, as in Japan and, more recently, the United States, many large companies using robots, particularly automobile companies, have themselves started to manufacture robots or have entered the supply side of the market through the creation of subsidiaries.

The number of companies that are financially controlled by large diversified industrial groups is increasing rapidly. Those companies that "pioneered" this sector are facing serious difficulties such as an inability to sustain the massive R&D burden, to find the working capital necessary to supply complex, fully customized robot systems and, finally, the problems involved in incorporating and developing the technological know-how and practical experience of applications required by the recent trend in the manufacturing sector toward the use of integrated automation systems.

Apart from Italy, the most important European manufacturers of robots

(see paragraph 2.3) are the following countries:

--Sweden: the limited size of the domestic market means that this country exports more than 50 percent of its production, covering approximately 20 percent of the European market for industrial robots;

The leading company in Sweden in this sector is ASEA;

--West Germany: there are 20 companies, both large (Volkswagen and Kuka) and medium-sized, operating in this sector. Also, a number of electronics companies such as Siemens have opened subsidiaries for robot manufacturing.

The other countries in Europe, on the other hand, have only recently started to manufacture and utilize industrial robots on a large scale:

--British industry was a latecomer to the sector of robot manufacture. In 1982 there were eight manufacturers in Britain, covering 25 percent of domestic demand. It was only recently that, thanks to the creation of new companies as a result of agreements made mainly with Japanese companies and the fact that foreign manufacturers located operations in this country, that this sector really started to develop;

--There are 12 major robot manufacturers in France. These are small, specialized companies, with the exception of Renault, which manufactures robots through its subsidiary, Acma-Caiber. The greater part of this production is destined for applications within the Renault group (in 1982, 50 percent of production was taken up by the group);

--Until now, Spain has basically been a user of robots. Following the establishment in Spain of manufacturing units of foreign companies such as ASEA (Sweden), the country is now entering the supply side of the market.

As things stand today, the main advantage that European manufacturers have over Japanese and U.S. manufacturers is the fact that they offer users modular systems which are specially adapted to suit different customer requirements.

In the long run, however, this advantage may well prove to be a double-edged sword, restricting the market potential of manufacturers and forcing them to adopt "niche" strategies, leaving the way clear for the standards used by the competition in the United States and Japan, something which would obviously have negative consequences for European

manufacturers.

This scenario could be modified to some extent if there were an increase in the number of cooperation agreements between European manufacturers and both Japanese and American companies.

1.3 World Demand

As we have seen, the majority of robot manufacturers are also the main users of robots.

However, with the spread of automated manufacturing processes to include all areas of manufacturing, and given that multinationals operating in the broader sphere of informatics technologies are now entering the sector, changes and developments are taking place in the structure of demand.

Japan: The main sectors of industry using advanced flexible systems, and robots in particular, are the mechanical engineering sector and transportation manufacturers. These are followed by the electrical and electronics sectors.

When one considers that Japan is both the leading manufacturer and user of robots, the fact that advanced forms of automation are restricted to the "traditional" sectors of mechanical engineering rather than being widely applied in other areas (such as rubber, plastics, and the timber industry) becomes significant. Moreover, approximately 30 percent of the robots manufactured are taken up by manufacturers of machine tools alone. This can be explained by the fact that advanced systems are being manufactured by companies which exploit the technology available to them to increase their own manufacturing efficiency and to establish the company image on both the domestic and international markets.

Europe: On the demand side, there is no market at a truly European level, with common technical standards or commercial structures. This means that there is no European company, however large and/or supranational, with a sufficiently large and protected internal market to make it successful at an international level.

As we have already seen, therefore, the European scenario is characterized by market fragmentation:

--In France there appears to be a fairly uniform distribution of robots, the major areas of application being the major groups in the automobile and industrial vehicle sectors.

As "large-scale users" these groups are still at the experimental

stage, both with regard to the internal organization of production and in terms of the support given to their own manufacturing units (in the case of groups which include robot manufacturers). However, domestic demand is not limited to these large-scale users alone. In fact 25 percent of automation systems in France are installed in small and medium-sized independent companies.

Therefore, demand in France is more diversified than in other countries, not only with regard to the sectors involved and the size of the user companies, but also--and this is the most interesting aspect--from the point of view of application. Given the slow rate at which demand has developed, and considering the uncertainties felt by those groups which either are or could become "user-manufacturers" of industrial robots, there seems to be an interesting potential for growth in the domestic demand.

--In Germany it is the smaller companies that have played a decisive role in the development of industrial robotics and flexible manufacturing systems. Only at a later stage, in fact, did the large industrial groups adopt automated manufacturing systems, mainly in the sector of transportation and the mechanical engineering sector.

During the design and production phase of a system, collaboration between users and manufacturers is important since, as manufacturers in Germany are mostly German, the domestic market has proved to be fairly unreceptive toward products exported by foreign manufacturers up until now.

We feel that in the near future the applications of robots will depend more upon the production potential of domestic users than upon the opening-up of new overseas markets.

--In Great Britain demand has not yet assumed a precise, clear-cut form, from which it would be possible to identify specific trends in its development.

Use of robots in the sector of agricultural and earth-moving machinery is fairly limited.

The same is true of machine tool manufacturers who, with the exception of Scamp, were relatively slow to implement "in-house" systems to be used as a test bench inside the company and a visiting card outside the company, a strategy widely employed by Japanese companies.

Companies acting as subcontractors in the mechanical engineering sector must be considered separately. The majority of these companies are

positioned at the lower end of the market and complete information is unavailable because of their size, despite the fact that Japanese manufacturers of flexible modules focus heavily on this segment. Actually, a large percentage of the companies using industrial robots and advanced manufacturing systems in general form part of larger industrial groups which are often under the control of foreign companies (usually U.S. companies).

All this leads one to believe that, in addition to the industrial policy measures discussed above, the introduction of flexible systems has been aided by the existence of an industrial culture of automation and innovation, which is probably most widespread in industrial groups with a diversified product range, capital formation, and manufacturing and marketing offices.

This is particularly true of large-scale systems requiring considerable technical, human, and financial resources. Given the elevated cost of industrial robots, the latter aspect is of major significance.

1.4 Development Trends

The fact that policies for the promotion of industrial automation exist, that there are varying degrees of integration between the financial sector and industry, that markets differ in size, that there are research centers and dynamic school and university structures; the fact that there is a receptive attitude from the business sector and, finally, the question of distances from major markets and sectors of application--these are only some of the aspects which have either helped or hindered the development of robotics in the different nations of the industrialized world.

What emerges from this picture of an uneven world market of robotics is that, of the 200-odd manufacturers of industrial robots in the world, Japanese companies are the most dynamic, tending toward a highly standardized production. It can also be seen that the Americans, who are more attentive to user requirements, have achieved a high technological level. Finally, we can see that the early activity of European manufacturers in this sector has been characterized by a certain amount of hesitation. Moreover, there are certain aspects that are common to all and which will certainly play an increasingly important role in deciding the direction of future developments in this sector.

These include:

The merging of, on the one hand, companies operating in the machine tool sector and, on the other, companies involved in the sphere of

informatics technologies and, at a more general level, electronics.

This sector has now gone beyond the "pioneering" stage and robot technology is now moving toward development of more complex systems of automation. This is producing a transformation in the supply side because of the fact that recently there has been a tendency among major companies who are end users of robots, particularly companies in the electrical and mechanical sectors, to incorporate small robot manufacturers because of their greater technical know-how and knowledge of applications. Moreover, "system" requirements and the increasingly sophisticated level of technology means that software (that is, system architectures, sensors, CAD/CAM, artificial intelligence) is gradually coming to assume a greater importance than hardware.

Internationalization of manufacturing: This represents a secondary aspect of the development scenario described above. What has happened over recent years is that a close-meshed network of links has been created between manufacturers of robots in different countries. Through this network, the "new forms" of internationalization--as opposed to the "traditional form" consisting of the creation of multinationals--can be seen in the shape of shareholdings, joint ventures, and collaborative agreements at both the technical and manufacturing levels. This process of supranational integration of robotics can therefore be regarded as the response of the main countries manufacturing robots to the financial and technical problems which have emerged as a consequence of the rapid development of this sector.

These agreements enable the Japanese to come to terms with the limited size of their domestic market. They mean that U.S. manufacturers can import the less sophisticated, standardized robots for handling operations manufactured by the Japanese and can subsequently upgrade them with the addition of controls, sensors, and other components produced with American organizational and commercial experience, integrating this with the technological expertise of the Japanese.

The gradual "shrinking" of the market to a few competitors--large multinationals capable not only of meeting the high levels of investment required for R&D and for the acquisition of technological know-how and knowledge of applications but also possessing powerful sales networks. This does not mean, however, that market "niches" will disappear, since these can be exploited by small, dynamic companies which are both flexible and highly innovative.

Changes in the structure of demand, with a gradual diffusion of automation processes within the manufacturing sector, with no constraints on the product sector or size.

Part Two

The Production of Industrial Robots in Italy and the Market for These Products

2.1 Development Characteristics

Two distinct characteristics have aided the birth and development of industrial robotics in Italy. These are:

--On the demand side, the growing request for automation on the part of companies faced with labor problems;

--On the supply side, the existence of an advanced machine tool idnustry with an advanced level of mechanical and electronic know-how.

With regard to the first point, these problems resulted in the spread of robotics in the major automobile companies (Fiat, Alfa Romeo) and manufacturers of household appliances (Zanussi). The effect of the second point, on the other hand, was to create areas of strength in terms of supply. These strengths can be summed up as follows:

--The availability of original technology;

--Production specializing in machines and systems for special applications (assembly, painting, welding, control, handling, supplying, and unloading of machine tools);

--A strategy of product diversification by the various manufacturers.

In addition to these positive factors, we must also mention the main constraints hampering the development of companies manufacturing industrial robots.

The first of these constraints consists of financial problems. In a market characterized by a high degree of technological risk and great international competition, the ability of a company to finance itself is not enough to guarantee growth, consolidation, and the launching of new initiatives.

Second, there is a lack of government support. The fact that "operating" obstacles exist limits a company's ability to gain easy access to government financing channels.

There are also a number of other constraints on company development,

including:

--Knowledge of applications. There is a considerable degree of know-how with regard to single robots but inadequate knowledge of applications of flexible assembly systems, in which robots are one of the main components;

--Training of technical personnel, nowadays carried out almost exclusively within companies because of the gap between industry and the education system in Italy;

--Increasingly fierce competition at an international level (particularly the Japanese). In this respect, Italian robot manufacturers could find that the "micro-company" structure characterizing their sector may well become a major weakness.

2.2 The Role Played by the Sector in the National Economy and at an International Level

At the end of 1984 there were more than 95,000 robots in the world (calculated on the basis of the most widely-used definition in the West, that is, excluding robots for manual handling operations and pick-and-place robots). Table 2 shows the distribution among some of the major Western nations.

An important aspect concerning the distribution of robots in the countries listed in Table 2 is the number of robots in use at the end of 1984 for every 10,000 employees in the manufacturing sector (Table 3).

Taking the manufacturing sector as a whole, if we analyze the figures for the automobile industry alone, we find that the Italian automobile industry is at the leading edge in terms of the number of robots used for every 100,000 vehicles manufactured (Table 4).

What we have said above is to some extent confirmed by the figures given in Table 5. From this table it can be seen that more than half the robots manufactured in Italy in 1983 were concentrated in the automobile industry.

Japanese manufacturers continue to hold a leading position in the world market for industrial automation, a sector in which robotics is one of the most important areas (Table 6).

2.3 The Supply Structure

In 1974 there were four companies in Italy in this sector. By 1985

this number had increased to 18. These companies manufacture robots mainly for handling, welding, and assembly operations (Table 7). The list given in Table 7 does not include companies manufacturing mechanical arms, as these are not classified as robots in the sense used in the West.

In addition to the above companies, we also have to take into consideration a vast number of companies operating in the sector of industrial automation, in which robots are one of the most important components. These companies include manufacturers of mechanical and electronic components, systems experts, and maintenance companies, public and private research centers, consultancy companies, and technological training companies. The birth of companies manufacturing industrial robots in Italy can be summed up in three main stages (Camagni: "The Italian Robot," 1984), which are:

--Subsidiaries of major users (e.g. Comau-Fiat, Ocn-Olivetti, Ansaldo Elettronica);

--Diversification of the machine tool sector (DEA, Davio, Bisiach e Carru, Gaiotto);

--Spontaneous growth on the part of technical personnel previously employed in mechanical engineering and electronics companies (Jobs, Prima Progetti, Camel).

At a more general level, "what made the birth of the robotics sector in Italy possible in the 1970s was the rise of a business sector with a technical background." (Camagni, op. cit.)

In 1983, the 18 companies listed in Table 7 employed a total of 846 people, with an average payroll of 47 people per company. This confirms the fact that the industrial robotics sector in Italy consists mainly of small companies (Table 8).

Given the high content of technology and innovation in this sector, the proportion of specialized personnel is extremely high. In 25 percent of companies, in fact, more than 90 percent of the employees are technicians or qualified engineers. Another aspect which shows that this sector is composed of small companies concerns sales. Fifty-six percent of companies have sales of less than 2 billion lire, with only 18.7 percent of companies coming within the top bracket, represented by sales of 10 to 20 billion lire (Table 9).

As regards the geographic distribution of industrial robot manufacturers, it is worth noting that these are concentrated exclusively in the north of Italy (Piedmont, Lombardy, and Emilia)

(Table 10).

A comparison with the distribution of employees in the machine tool sector generally bears out what was stated in paragraph 2.1 regarding the birth and development of robotics in Italy. In the three regions mentioned above, in which all robotics companies are located, the number of people employed in the machine tools sector represents only 60 percent of the national total. Table 10 shows the clear leadership of the province of Turin, which accounts for more than 55 percent of all employees in the robotics sector.

The categories of robots manufactured in Italy are shown in Table 11. The figures given in this table are based on a survey of Italian manufacturers.

The table shows the highly specialized nature of the products manufactured and the consequently low level of competition among comapnies (in each category, on the whole, each company has only a few competitors). It also shows the high technological level of the products, classified according to the control system of the robot.

From the balance of trade for this sector it can be seen that, up until 1977, imports outstripped exports. From 1978 onward, however, this trend was reversed, with export levels which were, on average, almost double those of imports (Table 12).

Exports of robots account for approximately 40 percent of total production. The main countries of destination are West Germany, France, Spain, Great Britain, the United States, the USSR, and Japan.

2.4 The Demand Structure

Beginning in the early 1980s robots have been regarded in terms of process innovation and have started to be used more widely in industry.

The 355 robots in existence at the end of 1979 increased to a total of 1200 by 1982 (Table 13), reaching the figure of 2,700 recorded at the end of 1984 (Table 2).

The main reasons for this increase are the following:

--Reduction and, wherever possible, elimination of tiring, monotonous jobs involving a high degree of risk;

--Increased productivity and a reduction in the labor cost;

--Improved product quality;

--More regular and, above all, more flexible production.

All this has created the bases--and, indeed, continue to do so--for the high degree of receptiveness displayed toward the introduction of automation in general, and of robots in particular, on the part of major automobile companies and manufacturers of household appliances, companies which operate on a mass production basis and which are more affected by social, economic, and labor problems and, finally, which have substantial financial and human resources available to them. However, demand for robots is spreading from these large companies to include medium-sized companies as well. For these companies, the last of the four points listed above could well prove to be the deciding factor, in that a more flexible production system would enable these companies to implement small series production to meet market requirements.

Demand for robots is more widespread in geographic terms than are manufacturers in this sector who, as we have already seen from Table 10, are all concentrated in the north of Italy (and, specifically, in Piedmont, Lombardy and Emilia). The data available in 1983 refer to robots manufactured in Italy and installed between 1979 and 1983. 86.5 percent of these robots are located in the north of Italy (with a peak of 56.8 percent in the province of Turin), 9.6 percent in central Italy, 21 percent in the south of Italy and the remaining 2.1 percent in Sicily.

From Table 13 we can also establish the type of demand which exists for industrial robots. 41.7 percent of demand is for robots for spot welding, followed by handling (16.7 percent), assembly (10.8 percent), painting and continuous welding (8.3 percent each; these two categories, though, showed the largest average increase in percentage terms between 1979 and 1982) and, last, measurements (1.7 percent).

From the analyses made of the development of demand for industrial robots it can be seen that the process is still only at the beginning of the logistic curve of product diffusion and that there is therefore still considerable growth potential. Nonetheless, we must not underestimate the role played by certain constraints which are likely to delay this potential growth. These include:

--The high cost of the machines;

--The difficulty, for the potential purchaser, of quantifying the cost/benefit ratio;

--The low level of technological awareness in the business sphere;

--The limited ability of companies to adapt organization of the manufacturing process to meet the requirements of automation.

2.5 Development Trends

An evaluation of the development prospects for robotics cannot be based on mere extrapolation from the situation we have today, in which the robot plays the more or less lonely role of an innovative machine within the manufacturing sector.

On the contrary, an evaluation of this kind must take into account the broader context of factory automation which, through processes of constantly increasing vertical and horizontal integration, will ultimately become the factory of the future. In this "factory of the future" the four traditional functions (design, production management, processing and assembly and, finally, movement and storage) will form a single integrated system (CIM - Computer Integrated Manufacturing).

In this scenario--which will be long term--the robot is no more than a component whose integration with the other components will force people to face complex and difficult problems. There is no doubt that experts consider such integration to be the main trend in the production of robots in the future (Table 14).

From a comparison of the trends shown under numbers 2 and 5 in the above table it can be seen that the situation we have today, in which the overriding concern is to manufacture robots which are essentially standardized, offered almost on a "catalog" basis, will be completely overturned.

From the manufacturer's point of view, there will be an increasingly clear distinction between:

--A few major manufacturers characterized by low cost production and long production runs;

--Small specialized manufacturers adopting "niche strategies."

It is also extremely likely that the majority of robot manufacturers will act as subcontractors to systems companies operating in the broader context of factory automation. On the demand side, on the other hand, we will have a situation in which demand from present users (that is, the automobile industry, household appliances, electronics companies) will spread to include other sectors (such as the timber industry, clothing and foodstuffs), as well as to civil and military applications (such as the handling of dangerous substances and freight movement in ports and airports).

Part Three

Problems in the Sector and the Outlook for the Future

3.1 The Role of Government

In the preceding sections we have seen that the major countries that are interested in developing industrial automation--in which robotics plays a fundamental role--make substantial provision for government intervention.

France and Great Britain have implemented a great number of measures with different objectives.

West Germany, on the other hand, has focused on providing a smaller number of measures of a more general nature.

The situation in the United States differs from that of other nations in that the greater part of the financial resources destined for industrail automation consists of a Defense Department budget allocation.

Japan has a large number of specific measures with precise objectives which are established in advance. Research and development financed by the state is far better coordinated and more "targeted" than in other countries, particularly the European countries. Moreover, contrary to normal practice in the United States, this type of R&D activity is not directly linked with military requirements.

Of all the countries mentioned, the one with the lowest level of government financing and the smallest number of specific measures of intervention is Italy. Because of this, it is difficult to evaluate with any accuracy the amount of financing allocated to industrial automation and to robotics in particular.

At present, three programs form part of the specific projects of the CNR [National Research Council]. These are:

--"Informatics," with 13 billion lire allocated to research into advanced process controls, CAD [Computer Aided Design] systems in mechanical engineering and interfaces with machines;

--"Mechanical technologies," with a budget of approximately 31 billion lire for the 3-year period 1983-88. The principal objective of the program concerns the development of machine tools and the integration of these products in flexible manufacturing systems (FMS), with a major contribution being made to lasers. The program, which is

managed by the CNR, will be implemented with close collaboration between research centers and industry;

--Robotics: the feasibility study for this project has not yet been completed.

In addition to the specific projects, there are also a few measures of a general nature. These are:

--The "Fund for Innovation" established under Law 46/82. This provides an incentive for technological progress and the innovation of products and processes in all sectors of industry (automobiles, electronics, iron and steel, aeronautics, chemicals);

--Law 696/83: This law, which continues the initiative established under an earlier law of 1965 (the "Legge Sabatini" [the "Sabatini Law"]), constitutes an important support tool for industrial automation.

With an initial budget allocation of 100 billion lire, it provides grants toward the cost of purchasing or leasing technologically advanced machine tools.

Finally, mention must also be made of the "IMI Special Fund for Applied Research," even though the objectives of this measure are extremely wide-ranging and general.

3.2 Similarities and Differences Compared with the International Situation

A comparison, from the point of view of quality and of the supply and demand characteristics in the sector of industrial robotics in the three major areas of the world (Japan, the United States, and Europe) enables us to trace a reasonably faithful and detailed picture of the situation in Italy compared to the international scene.

First and foremost, it can be seen that there are a greater number of points of divergence in Europe than in Japan and the United States. This means that behavior in Europe is more in keeping with the real situation in industrial robotics in this area.

While--given our geographic location and economic standing--this is understandable from a historical point of view, when we put it into perspective it could well represent a weakness when set against the ambitious development programs of the Americans and Japanese. This would be especially true if we were to find ourselves unable to formulate a common and effective European industrial policy.

The main areas of concern compared with the international situation are:

--The low level of interaction between government bodies, universities and industry. Attempts are being made to promote such interaction through the launching of the CNR specific projects;

--The limited amount of government support to both public and private R&D work;

--The lack of adequate structures in schools and universities for the training necessary for future development of the industrial robotics sector;

--The lack of awareness in the business sector regarding automation and robotics.

3.3 The Outlook for the Sector

The lines along which the industrial robotics sector is developing are increasingly concerned with:

--Integration of the different machines which constitute the "processing cells" in order to make them fully compatible and interconnected;

--Modular automated manufacturing systems;

--"Intelligence," that is, the ability of the robot to adapt itself to its surrounding environment and, consequently, to act on the basis of the data transmitted to it by means of the viewing systems and sensors with which it is equipped;

--System flexibility and versatility, based on the various operating requirements within the manufacturing process;

--The development of software and of the ability to process the data received from the surrounding environment.

This means that the number of cases in which single robots are used will consistently be reduced and that the use of highly computerized manufacturing systems will become increasingly common.

At the same time, we will find ourselves faced with a situation which the Japanese (Flexible Manufacturing Complex) and the Americans (Manufacturing Automation Protocol) are already having to come to terms with. This concerns the need to establish common standards for

industrial automation products so that these products can be fully integrated and so that the cost of manufacturing these products can be considerably reduced by extending and combining international markets.

Finally, R&D activity will also assume great importance. This activity will mainly be oriented toward creating, for purposes of application, an interconnection between existing technologies and mechanical and electronic know-how.

On the supply side, we will be faced with the situations we have already discussed, that is, internationalization and merging of the sector of manufacturers who have traditionally been involved in informatics technologies. What we will also find, however, is an increasingly clear distinction between, on the one hand, a small number of large manufacturers operating at an international level and, on the other hand, small and medium-sized companies in a position to exploit specific areas of the market or who essentially act as subcontractors.

Moreover, the "spin-off" from the industrial automation sector is destined to increase (system houses, complementary services of complex software, assistance and system reprogramming, maintenance, consultancy for organization and design, training), with an increasingly pronounced tendency toward specialization.

The degree of integration between Italian manufacturers will gradually increase, and the result of this will be to rationalize the sector. This does not mean, however, that international agreements will be restricted in any way. These agreements are necessary both to combat the limited size of the internal market and to acquire technological expertise from other countries.

On the demand side, large companies will continue to be the main users of automated manufacturing systems, both for "strategic" reasons (that is, increased productivity, reduction of hourly costs, and a recovery of flexibility) and for objective reasons of a financial nature (the fact that high initial capital investments are required).

Nonetheless, the market offering the greatest potential is that of medium-sized companies. The reason for this is that, in order to be competitive on international markets (which means that a company has to be able to adapt production rapidly to meet demand and must be able to differentiate its products), these companies will tend more and more to utilize flexible manufacturing systems with a high degree of automation.

The factors which will influence the development and orientation of demand are the following:

--The diffusion of technical and financial information on the utilization of robots;

--The organizational structure of manufacturing comapnies, which will have to be able to guarantee a complete assistance service from the design phase through the time the system comes on line;

--The availability on the market of integrated automation systems which are flexible and reliable, and which are capable of satisfying the wide variety of individual customer requirements;

--Suitable financial incentives intended to promote the adoption of robots and cover part of the high initial capital investment required.

Moreover, vast new markets will emerge in the form of civil and military applications. The domestic market will also offer substantial growth possibilities.

The diffusion of industrial automation technology and of integrated manufacturing systems in particular will, in the long term, have a direct effect on all areas of manufacturing. It will also have indirect effects on the entire production system and service sector.

At a national level and in parallel with this, highly automated manfuacturing will gradually become decentralized. This will lead to the creation of new manufacturing and market opportunities in peripheral areas.

3.4 Conclusions

Although there are some negative aspects to the description of the sector given above, the position of Italian manufacturers can on the whole be considered to be satisfactory.

The technological know-how acquired both in the sector of mechanical engineering and in the electronics sector means that Italian companies hold a leading position in a number of important segments of the industrial robotics sector.

If these development factors are to be consolidated further, demand at the national level must first be strengthened and "guided."

Given the highly competitive nature of U.S. and Japanese products and the fact that the sector of industrial automation in these two countries receives direct and indirect support from the respective governments, what is needed in Italy in this case is government

intervention in at least two areas.

First, demand from the state sector is needed, both on the manufacturing side and in the service sector. This demand would be oriented toward the application of automated systems and would enable manufacturers to focus their attention on medium and long-term programs, thereby acquiring specific technological know-how in that particular market.

Government orders, which would specify the technological and functional characteristics of the system required and would establish specific objectives for manufacturers would, in this case, have positive effects on the level of competitiveness of the sector. They would also enable manufacturers to program production more effectively.

The second area in which government intervention is needed concerns the provision of incentives to increase the demand for flexible manufacturing systems, particularly from small and medium-sized companies. The measures which could be adopted for this purpose include:

--Implementation of channels of information concerning the potential applications of industrial automation technologies and the "financial effects" that process innovation of this kind would have on company activity;

--The provision of incentives to purchase automation systems. This could be done by contributing a certain percentage either of the purchase cost or of the leasing installments. Law 696/83 establishes a mechanism of this kind and, given the positive results which have already been achieved, should be maintained and refinanced;

--The provision of contributions toward consultancy services, feasibility studies, project planning, and implementation studies for potential purchasers of industrial robots and flexible manufacturing systems.

This does not mean, however, that other areas of intervention should be neglected. These include:

--Support for R&D activity oriented toward, on the one hand, the development of robot technology, with special emphasis on the areas of artificial intelligence, software, sensors, and control systems and, on the other hand, the development of operating applications of robots, from the prototype phase through to the manufacturing phase;

--Direct and indirect support for the training of specialized

personnel;

--The creation of synergies between government research centers, the manufacturing sector and universities, achieving this through the implementation of faster, more accessible information channels and the approval of specific projects to be conducted on a joint basis.

At a national level, the process of diffusion of manufacturing automation could be promoted both through the creation of a greater awareness on the part of local bodies (regional authorities and local organizations, chambers of commerce, business associations, and banks and financial institutions) as well as through the provision of incentives for the creation of technological and science parks.

All this would have positive effects (which would be cumulative) not only on the productivity of single companies, but also on the efficiency and, consequently, the competitiveness of the entire industrial system. The imbalances in employment that would inevitably occur could be absorbed in the medium term by the growth of new services and new areas of activity related to this sector.

Table 2

Japan	64,000
U.S.	13,000
West Germany	6,600
France	3,380
Italy	2,700
U.K.	2,623
Sweden	2,400
Belgium	859
Spain	518

Source: "The Industrial Robot," March 1985

Table 3

Japan	32.0
Sweden	17.7
Belgium	6.4
West Germany	5.7
U.K.	4.8
France	4.3
U.S.	4.3
Spain	3.8
Italy	3.5

Table 4

	No. robots in service	No. robots in service per 100 thousand vehicles produced
Toyota	1,250	59
Nissan	1,300	45
Mazda	360	32
Honda	340	34
Mitsubishi	230	24
VW	820	55
Renault	240	14
PSA	200	15
Fiat	600	60
Ford (West Germany)	250	48
Ford (U.K.)	160	38
Opel	40	4
U.S. GM	2,300	57

Source: Nomura - March 1984

Table 5

Sector	Percentage of robots
Transportation, of which:	56.0
Auto + components	50.4
Mechanical	16.5
Electronic	19.5
Other	8.0
	100.0

Source: "Mondo economico," 26 May 1984

Table 6 Percentage distribution of the world market in 1983

U.S.	25
Japan	50
Europe	20
Rest of the world	5
	100

Source: "Mondo economico," 26 May 1984

Table 7 Italian robot manufacturers

	Welding	Painting	Handling	Assembly	Measure.	Other
Piedmont:						
Comau Fiat	X	X	X			
Ocn Olivetti			X			
Dea			X	X		
Prima Progetti	X		X		X	X
Bisiach Carru	X					
Olmat		X	X			
Lombardy:						
Ansaldo	X		X			
Camel			X			
Basfer		X				
Norda			X			
Samac				X		
Gaiotto		X				
Aisa			X			
SLS		X				
Duplomatic			X			
Meccanica Speroni					X	
Emilia Romagna:						
Jobs			X			
Savio		X	X			

Source: Camagni, "The Italian Robot," November 1984

Table 8 Size of the robotics sector 1983

Employees	No. companies	Percentage	No. employees	Percentage
0-10	3	16.7	23	2.7
10-20	5	27.8	79	9.3
20-50	4	22.2	160	18.9
50-100	4	22.2	274	32.4
100-250	2	11.1	310	36.7
	18	100.0	846	100.0

Source: Camagni, "The Italian Robot," November 1984

Table 9 Turnover in the robotics sector in 1982

Turnover (in billions of lire)	No. companies	Percentage
0-1	6	37.6
1-2	3	18.7
2-5	3	18.7
5-10	1	6.3
10-20	3	18.7
	16	100.0

Source: Camagni, "The Italian Robot," November 1984

Table 10 Geographical districution of employment in the machine tool industry (1981) and robotics (1983)

	No. empl. mach. tools	Percentage	No. empl. robotics	Percentage
Turin	19,835	20.81	468	55.32
Milan	17,890	18.77	99	11.70
Varese	5,496	5.77	26	3.07
Pavia	3,067	3.22	77	9.11
Brescia	5,760	6.04	56	6.62
Cremona	1,075	1.13	50	5.91
Piacenza	904	0.94	52	2.13
Bologna	4,194	4.40	18	6.14
Piedmont	19,835	20.81	468	55.32
Lombardy	33,288	34.93	308	36.42
Emilia	4,194	5.34	70	8.27
Total manu. area robotics	58,221	61.08	846	100.0
Rest of Italy	37,096	38.92	0	0
Total Italy	95,317	100.0	846	100.0

Source: Camagni, "The Italian Robot," November 1984

Table 11 Robots produced in Italy

Application	No. manufacturers	Type of control	No. manufacturers
Handling	10	Manual	-
Painting	3	Fixed sequence	1
Welding	5	Variable sequence	4
Assembly	5	Playback	5
Measurement	3	Numerically cont.	7
		Comp. num. cont.	5
		Direct num. cont.	3

Source: Camagni, "The Italian Robot," November 1984

Table 12 Balance of trade in the Italian robotics sector

	1975	1976	1977	1978	1979	1980	1981	1982	1983
Imports (units)	40	60	120	40	40	65	82	70	82
Exports (units)	20	30	60	90	160	158	143	138	137
Imports (bill. lire	1.8	2.8	6.4	2.2	2.3	3.6	6.0	6.4	10.8
Exports (bill. lire	0.2	0.4	1.5	3.1	7.5	5.9	8.1	12.8	18.8

Source: Camagni, "The Italian Robot," November 1984

Table 13 Servo-controlled robots installed in Italy

Manufacturing process	End 1979	1980	1981	1982	Av. perc. increase	Total
Spot welding	220	30	70	180	32	500
Handling	30	40	40	90	88	200
Assembly	60	10	30	30	29	130
Painting	10	10	30	50	115	100
Cont. welding	10	10	30	50	115	100
Measurement	5	5	5	15	82	30
Other	20	20	30	70	91	140
Total	355	125	235	485	50	1,200

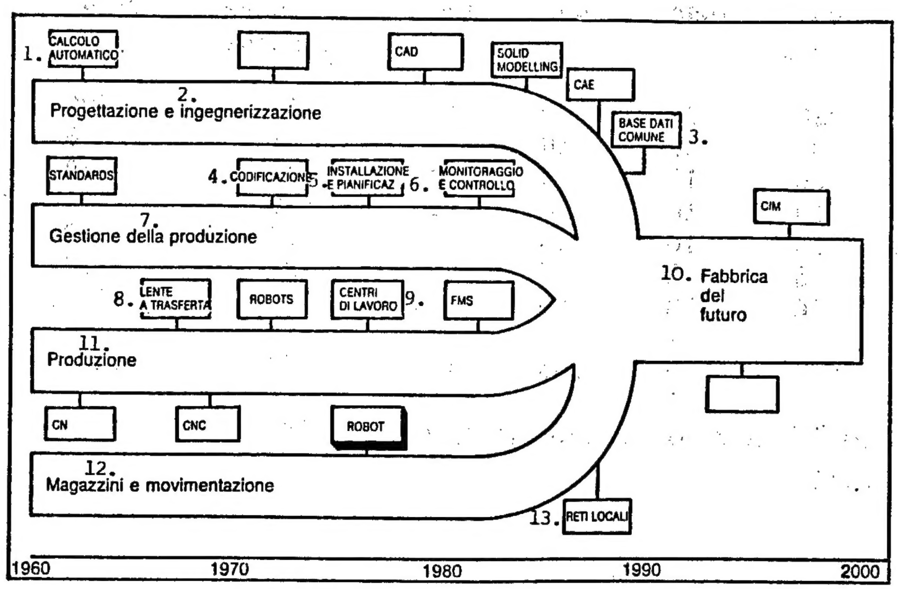
Source: Camagni, "The Italian Robot," November 1984

Table 14 Trends in robot manufacturing (percentage of positive replies to a survey conducted on 18 Italian robot manufacturers)

1.	Integration with other components in complex systems	100
2.	Increasing use of sensors	88
3.	Increasing standardization of parts	70
4.	More specialized robots	65
5.	Increasingly anthropomorphic appearance	29

Source: Taken from Camagni, op. cit.

Diagram 1 The process of factory automation



14 (Fonte: Elaborazione su schema «Reseau»)
15 Legenda: CAD = Computer aided design
CAE = Computer aided engineering
FMS = Flexible manufact.systems
CN = Controllo numerico
CNC = Controllo numerico computerizzato
CIM = Computer integrated manufact.

Key:

1. Automatic computation
2. Design and engineering
3. Common data base
4. Coding
5. Installation and planning
6. Monitoring and control
7. Production management
8. Transfer lens
9. Work centers
10. Factory of the future
11. Production
12. Storage and movement
13. Local networks
14. Source: Taken from "Reseau" diagram

15. Abbreviations:
CAD = Computer aided design
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CIM = Computer integrated manufacturing

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